Factors of Influence in the Results of 3D Measurements: Software Associated with Coordinate Measuring Machines

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Authors' contributions

This work was carried out in collaboration between the three authors. The three authors read and approved the final manuscript.

Original Research Article

ABSTRACT

In three-dimensional metrology, the means of 3D measurements have been widely multiplied in recent years, in metrology laboratories, in production workshops, with the evolution of technology in general, the software associated with these machines are multiplied and allow to obtain the results of measurements with different methods.

In this article we carry virtual measurements on a part, using two different software associated with coordinate measuring machines, but without the CMM. To do this we use the same measurement procedure in these two software, the least-squares method is applied for the evaluation of the geometrical specifications of the part.

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The results obtained by the two programs are compared with the nominal values.
The article highlights the hypothesis that the software contributes in the 3D measurement results; this approach allows the CMM measurement controller to know what measurement her software, before doing physical measurements on the CMM.

Keywords: Virtual measurements; software; CMM; uncertainty; 3D measuring means.

ABBREVIATIONS

3D   : *Three-dimensional*
CMM   : *Coordinate measuring machine*

1. INTRODUCTION

Three-dimensional metrology initially made it possible to realize the geometrical defects of mechanical products. As hardware and software developments evolve, resources are increasingly of good precision. Nevertheless, the more difficult part to master for the controller is the software tool by adapting as best as possible the control of the specifications of the products. Therefore, one of the major problems for many industries and laboratories using 3D means is the estimation of measurement uncertainties for each of the measured geometric specifications. Measurement uncertainties are a function of many factors. Very few 3D control reports reveal uncertainties in the estimated measurements. Only the uncertainties of the measured points are defined by the manufacturer and checked during the verification of a machine.

Three-dimensional measuring machines (CMMs) have become widely used in metrology laboratories and workshops. The software associated with these machines has grown considerably, making it possible to work on the basis of the numerical definitions of the parts to be checked. However, the reliability of the measurements remains difficult to quantify and the calculations of uncertainties are not made according to the rules of the art or take too long!

Several studies have been carried out on the subject of 3D measurement means (CMMs), to determine the parameters of influences of uncertainties in the measurement results, and other studies have shown the concept of virtual measurements of CMM, and evaluation methods Of the geometric elements [1-3]. But these studies are generally based on physical measurements of parts.

After several studies and experiments in 3D control, we found it is important to compare the software associated with CMMs, to know the influence of the software without the CMM, on the geometrical elements, using virtual measurements.

We pose the problematic focused on the software part of 3D measurement means, this new problematic studied pose any questions: Do we Do we get identical results of the virtual measurements of the same part, with the different software for CMM?

These software do not contribute to the measurement results? and how do we compare these software? to answer these questions, we realize virtual part measurements using point clouds with software associated with coordinate measuring machines. But we do not use CMM in our experiments.

1.1 Context

The objective of our research in general is to propose a pragmatic methodology or tool for estimating measurement uncertainties that takes into account more factors of possible influences in the results of measurements. But in this paper we focus on the problematic presented in the introduction, the software part can be a factor of measurement uncertainty, the results of this experiment allow the controllers of 3D measurement means to realize in the estimation of measurement uncertainties related to software tools in the results. To do this we realize virtual measurements with 3D measurement software, without the machines. And the results are compared whit the nominal values.

We use two types of 3D measurement software, for building virtual parts from point clouds. In order to analyze the results of measurements, we have set up a single procedure and a single evaluation method for all software. In order to measure the deviations of form, orientation, and geometrical elements, one of order of elements is respected in the program.

1.2 Experimental Study

The object of the experimental study is to construct geometric elements of a virtual part and to verify the geometrical specifications by the

same method and the same measurement program on the different 3D measurement software and to compare the results of measurements with the nominal values.

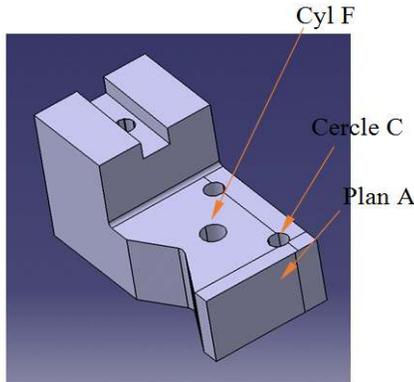Fig. 1 shows the 3D design of the experimental part.

Fig. 1. Experimental part 3D design

2. MEANS OF MEASUREMENT AND MÉTHODS

2.1 Means of Measurement

The means used in these experiments are the software of 3D measurement means for the Technical Center of Innovation MECA3D - Laboratory MIP2-Metrology Quality Digitization, INSA of Lyon. These software are associated with three-dimensional measuring machines, they make it possible to obtain the palpated points (contact between the probe and the surface of the part to be checked), the association of the geometrical elements and the verification of the geometrical specifications, and also the Virtual construction from clouds of theoretical points.

The software used in this study are:

Metrolog XG and CMM Manager, Metrolog XG is the most used software in this field.

Table 1 shows the software used with their specifications.

Table 1. Software used

Software	Reference
Metrolog XG 13 (10 /2010)	M8.1250.XG 13 Serial No.: 9479
CMM Manager 3.4 (04/2015)	2015-1105 Version : 3.5.2.3537

2.2 Method

There are many methods of association of elements, some are developed theoretically in algorithms without being implemented the software, others described in the scientific literature. It is imperative to know the methods available in the software to make the best measurements, since not all software have all the methods.

The method we chose for our study is available in the software used. The method of least squares.

The least squares method is a criterion that minimizes the sum of the deviations (e_i) from the squares of the points to the ideal element, regardless of the number of points, and regardless of the extent of the surface measured, this criterion has the advantage over other criteria of giving a reliable and robust result whatever the number of points and whatever the extent of the measured surface [4-6], it is defined by a function W in the following way:

$$W = \sum_{i=1}^{n} e_i^2$$

Fig. 2, shows a plane and a circle of least squares.

Fig. 2. Plane and circle of least squares

2.3 Measurement Procedure

To realize virtual measurements, we have made a unique measurement program for all software in order to overcome the procedural influences in the measurement results,It consists of the following steps in an order elements:

- Import points cloud,
- Identification of building elements,
- Construction of flat, straight, point,
- Creating the part mark,
- Construction of cylinders,
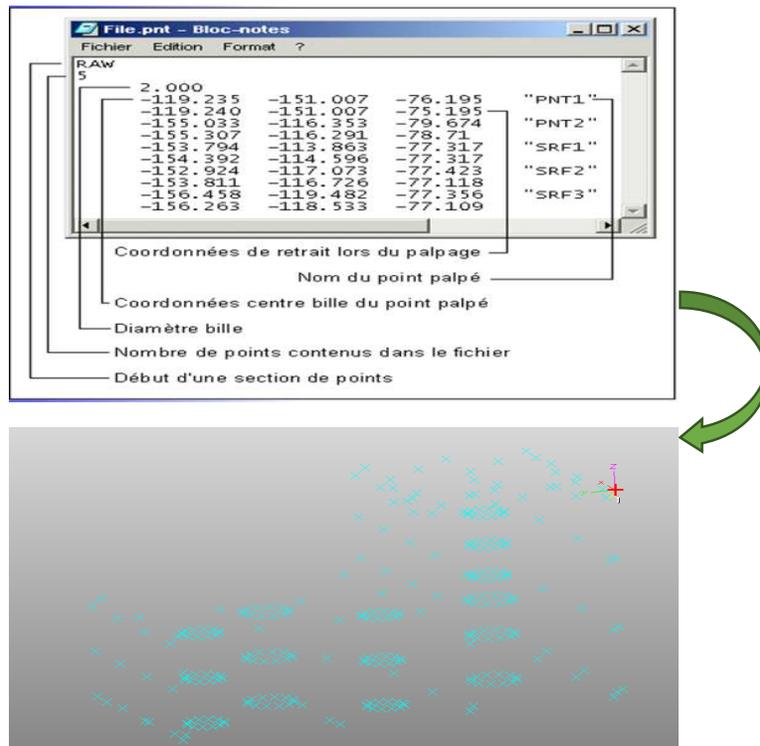- Evaluation of geometric specifications.

Fig. 3. File type and point cloud

The point files are converted to the software format using a macro.

Fig. 3 shows the file type of points and point cloud.

In this article we present the results of the geometric specifications presented in Table 2.

Table 2. Specification and nominal valeues

Specifications	Nominal values
Flatness(µm) *of plane A*	0
Circularity(µm) of circle C	0
Diameter (mm) of cylinder F	10 mm
Cylindricity(µm) of cylinder F	0.1 µm

3. RESULTS AND DISCUSSION

With the application of the approach we have obtained identical results with different software, in evaluating geometric specifications, and measuring geometric elements using the same program, but the values obtained are enough far from nominal values.

The flatness of the plane A (Fig. 5) has a nominal value zero (0) and that evaluated by the software is 0.118 µm, the cylindricity of the cylinder F

(Fig. 7) of nominal value zero (0), we obtain 0.1 µm, the circularity of the circle C (Fig. 8) evaluated by the software is 0.163 µm while the nominal value is 0.1 µm. In these experiments only the measurement of the diameter of the cylinder F (Fig. 6) the results obtained by the software are identical with the nominal value. We applied our study on the case most practiced by the controllers of 3D during a control of a part on CMM, so the results presented in this article are the averages of three measures of the program, on each of the software.

The vertical axis of graphs present the nominal values, the values of the geometric elements measured and the evaluated specifications, the software are presented on the horizontal axis.

Fig. 5 illustrates the results of the flatness evaluated by the two software programs.

The results of measurement of diameter of the cylinder of 10 mm, of the software are presented in Fig. 6.

In Fig. 7, we present the values of the cylindricity evaluated by the two software programs.
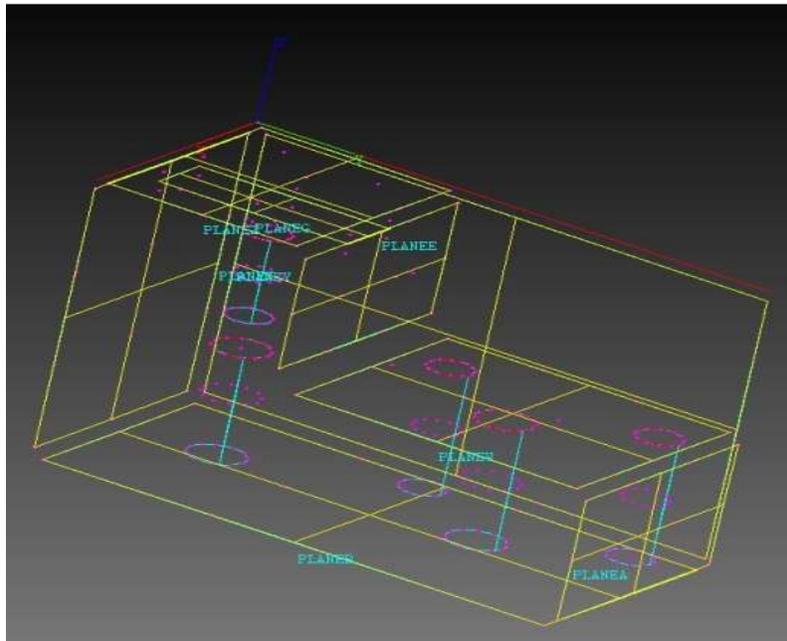
Fig. 4. Representation the association of the geometrical elements of the part
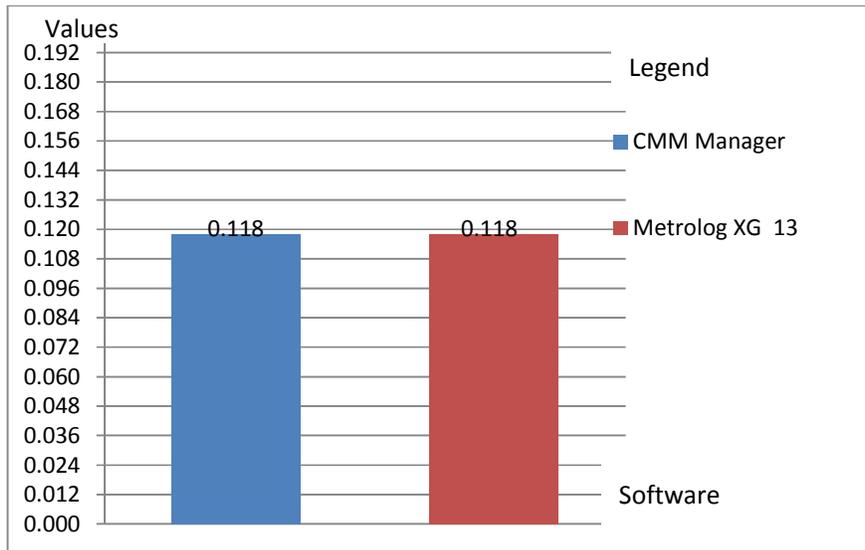

Fig. 5. Flatness of plan, obtained from different software

In Fig. 8, the results of the evaluation of the circularity of the circle.

In Table 3, we present the deviations (between the measured values and the nominal values) of all the geometric specifications evaluated by the Metrolog XG 13 software.

Table 3. Deviations evaluated by metrolog XG 13

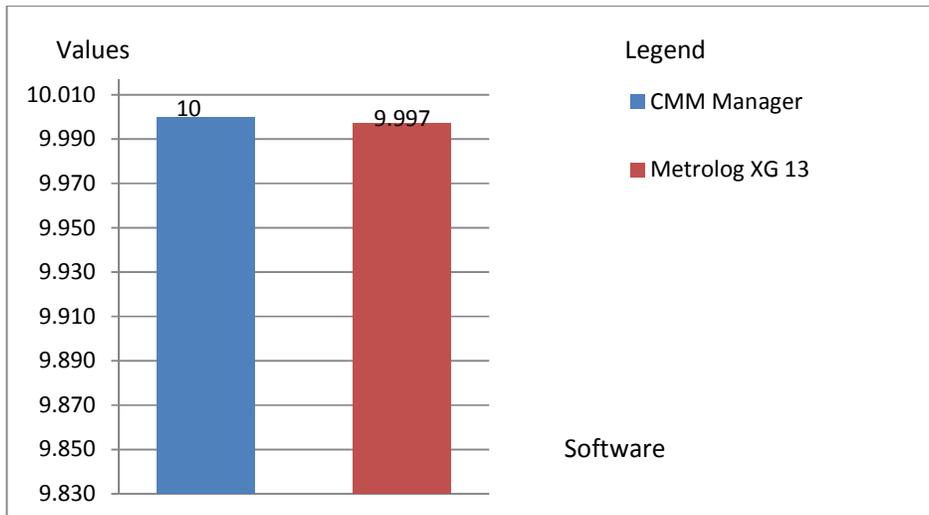| Specifications	Nominal values	Measured values	Deviations
Circularity	0,1	0,1630	0,0630
Cylindricity	0	0,100	0,1000
Flatness	0	0,118	0,1180
Diameter	10	9,997	0,0030

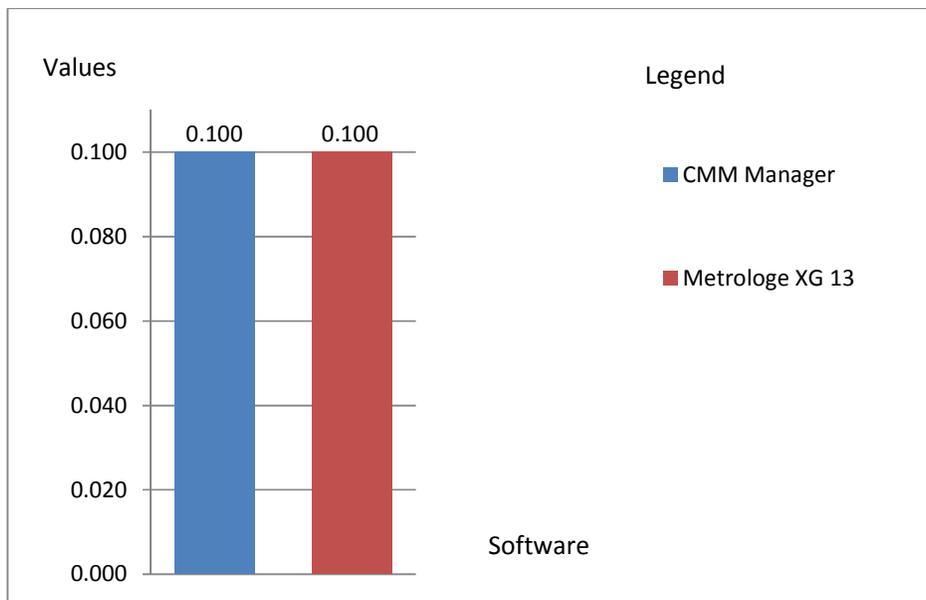**Fig. 6. Measurement results cylinder diameter 10 mm**

Fig. 7. results of the evaluated cylindricity

Table 4. Deviations evaluated by CMM manager

Specifications	Nominal values	Measured values	Deviations
Circularity	0,1	0,1630	0,0630
Cylindricity	0	0,100	0,1000
Flatness	0	0,118	0,1180
Diameter	10	10	0,000

In Table 4, we present the deviations (between the measured values and the nominal values) of all the geometric specifications evaluated by the CMM Manager software.

Table 5. Comparison of deviations of two software

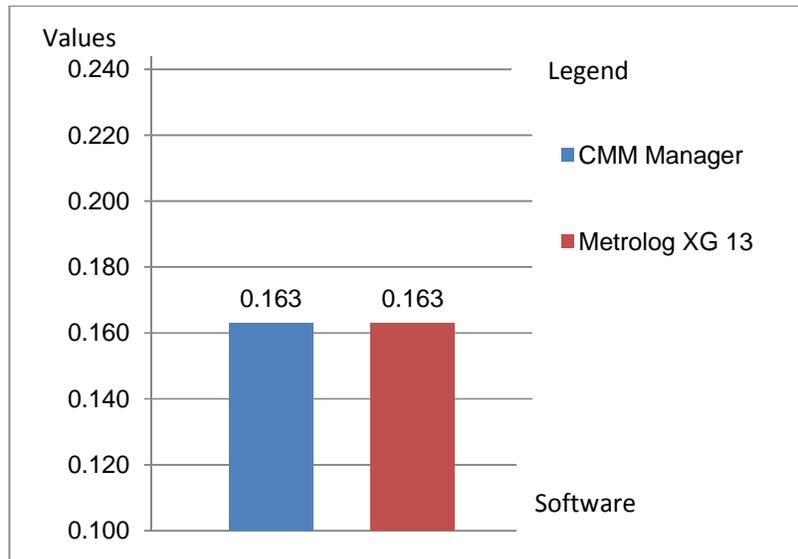| Specifications	Nominal values	Metrolog XG 13	CMM manager
Circularity	0,1	0,0630	0,0630
Cylindricity	0	0,1000	0,1000
Flatness	0	0,1180	0,1180
Diameter	10	0,0030	0,000

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Fig. 8. Circularity of the circle

The Table 5, shows a comparison of the deviations obtained by the two software programs, we find that the results are identical except on the diameter, but the difference is not significant.

4. CONCLUSION

In this paper, we have experimented with virtual measurements from point clouds In this paper, we have experimented with virtual measurements from point clouds, by two different software using the same procedure of measurement with the method of the least squares. We obtained identical results with the two software used, but in these results the deviations are large compared to the nominal values.

In metrology, these results confirm the influence factor of the software part in the measurement results, as other studies [7-9,2,3,10], have shown the influencing factors of the uncertainties of the three-dimensional measuring machine.

For metrology laboratories and industries, the software part is difficult to master, which is why the software influencing factor is ignored in parameter list of influences of measurement uncertainties. After our experiments and these results, we are led to ask the following questions:

How many controlled parts are declared non-compliant due to the software part?

The 3D control software associated with the CMMs meets the requirements set by ISO standards [11,12]?

Why not standardize the software development algorithms associated with CMMs instead of certifying?

It is necessary to realize virtual measurements to know the influences of the software associated with the three-dimensional measuring machine, in order to make decisions on measurement results and comply with the normative guidelines [13] which requires that each measure be accompanied by its uncertainty.

Knowledge of influencing factors is an essential step in the estimation of measurement uncertainty.

In this article we have evoked a new approach, which can allow the CMM measurement controller to take the influence factor of the software in the measurement results.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Pawel Swornowski, Miroslaw Rucki. The errors occuring in the CMM fitting method.

2. Wolff V, Tran Dinh T. Comparison of a machine of measurement without contact and a CMM: Optimization of the process of metrology; 2011.

3. Pawel Swornowski. The influence of the CMMs software on the results of calibration performed with the ball standard.

4. Raynaud S. Three-dimensional control; 2009.

5. Bernard Anselmentti. Metrology with ISO standards. 2011;5.

6. Wadel C. Reference guide for the calculation of measurement uncertainties on a coordinate measuring machine; 2006.

7. Bourdet P. Software for three-dimensional measuring machines, engineering; 2005.

8. Jalid A, Hariri JP Senelaer, Elgharad A. Evaluation of measurement uncertainties on a coordinate measuring machine: New method for estimating surface parameters and associated uncertainties, 9th French Congress of Mechanics, Marseille 24-28 August; 2009.

9. Trenk M, Franke M, Dr. Schwenke H. The "Virtual CMM" a software tool for uncertainty evaluation – practical application in an accredited calibration lab.

10. Weckenmann A, Knauer M. The influence of measurement strategy on the Uncertainty of CMM-Measurements.

11. XP ISO/TS 15530-4, Geometrical Product Specifications (GPS), Coordinate measuring machines (CMM): Technique for determining the uncertainty of measurement Part 4: Evaluating task-specific measurement uncertainty using simulation.

12. NF EN ISO 10360-6, February, Geometric Product Specification (GPS), Part 6: Estimation of Errors in the Calculation of Associated Gaussian Elements; 2002.

13. JCGM 100: 2008(F), Evaluation of measurement data, Guide to the expression of uncertainty in measurement; 2008.

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